Intelligent Online Measurement and Management of Energy Meter Data Through Advanced Wireless Network

Tanmoy Maity
Department of Electrical Engineering
Indian School of Mines
Dhanbad, INDIA
tanmoy_maity@yahoo.com

Partha Sarathi Das
Department of Electrical Engineering
Durgapur Institute of Advanced Technology and Management, Durgapur, INDIA
partha_san79@rediffmail.com

Abstract— **Recently the Electrical supply companies are trying to adopt the electronic measurement of energy consumption data because of reduced manufacturing cost, improved measurement accuracy, increased timely information, miniature size and many other benefits that go well beyond the traditional rotor-plate energy meter type. In this paper with the help of an energy chip, an improved energy metering solution is developed, where automating the progression of measurement through digital wireless communication technique is adopted to get the above benefits alongwith smooth control. The developed energy meter calculates the total average active power mainly for residential consumers. The hardware circuit accepts single phase voltage and currents as its inputs and provides the output in the form of logic data proportional to the average real power. This data is fed to a remote computer server through the wireless ZigBee network that represents the concept of distant wireless metering, practically involving no manpower. This paper also presents a software solution developed for total electrical energy billing and data management system.**

Keywords- Energymeter, wireless, automatic meter reading, database management.

I. INTRODUCTION

Automatic meter reading (AMR) is popular because of its remote nature of data collection. There are different technologies being used to capture and transfer data remotely, but the accuracy, speed, efficiency, reliability and cost-effectiveness are the usual benefits that should be properly achieved using this system. AMR is defined in [1] as the communication link, complete from the meter to the utility headquarters. The automatic meter-reading system employs distributed structure, consists of measuring meters, sensors, intelligent terminals, management centre and wireless communication network [2]. The meter reading and management processes are free from human errors. This system also gives many advantages over the traditional metering system such as the eradication of manual meter reading costs, improves customer services by reducing the maltreatment of data and replaces the difficulties like involvement of distance and accessibility of measurement points. With the advancement of new modern computer technologies, chances for more well-organized management of electric power distribution are there. The increasing importance of more accurate energy measurement data and real-time access to that data is accelerating acceptance of the digital metering technology [3]. The data communication is an important part of the AMR system. The communication system should be accurate, reliable and cost effective. To evaluate the type of communications network needed to carry metering data, it is necessary to review the type of customer infrastructures that could be interfaced to such a network. The primary role of the energy meter system is to provide daily usage, total usage and real time usage data to the consumers. As for the automation of the power distribution system, its development and practical application have become an urgent task to achieve efficient operation of equipment and high reliability for increasingly complex and expanding distribution systems [4].

For successfully wireless data transmission, in this paper the ZigBee specification is utilised. There has been increased interest in the ZigBee standard recently, in particular for building automation and industrial controls since its release in 2004 [5]. People prefer using this standard network among different wireless protocol for diversified applications. In [6], an agent-based wireless local positioning system with ZigBee technology is proposed, mainly for factory level applications. A cost effective ZigBee-based wireless mine supervising system with early-warning intelligence on methane, temperature, humidity in mining area is presented in another article [7]. Again, another article [8] presents the development of a system integrated to a ZigBee network to measure the whole human body vibration, for the persons exposed to vibratory environment. So ZigBee specifications are incorporated by many manufacturers in their device design. In the work presented here Chipcon make CC2430 Zigbee product is used for the wireless transmitting and receiving data from a single-phase energymeter, which is commonly used for residential consumer. This will benefit both the consumer and the service provider of electricity.

II. DESCRIPTION OF THE SCHEME

The whole system developed can be divided into three sections. First is a hardware based chipset solution of energy-meter that measures real-time active power from any single phase system. Second part is the data transmission, where a

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number of meter reading can be transferred through a wireless ZigBee based network to a remote server. The third part is the improved data management system based on user friendly software with two separate access support – one for consumer and another for the electric supply company. The first two sections are shown in a block diagram in Fig. 1. The separate sections are described briefly below.

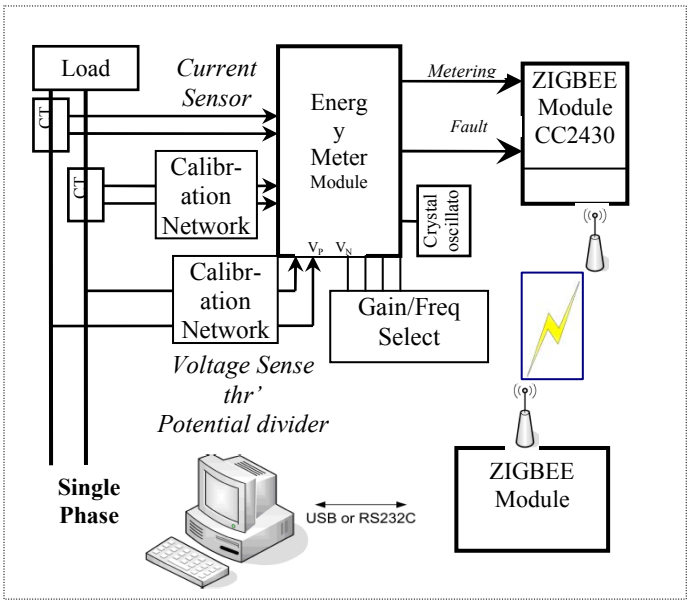

Figure 1. General Block Diagram Of The Scheme

A. Energymeter

The analog IC chip ADE 7751 is the heart of this hardware system of Energymeter. It is a high accuracy single phase electrical energy measurement chip with an active power logic output. The single phase supply voltage is fed directly to the IC through a resistance divider and calibration network circuits. The neutral line is connected to the ground point of the circuit board. The IC requires two sensing of the load current, one at phase and one at the neutral. Two current transformers (CT) of the same specification with appropriate burden resistances are used here. This is done to find difference of currents in phase and neutral, if any, resulting due to a fault in the load side. By doing this, it is possible to provide to the IC the magnitude as well as phase orientation of current. Thus the IC is getting phase angle between the load current and the voltage. The circuit can accurately calculate the average real power from those data for any kind of load like – resistive, inductive and capacitive. The functional block diagram of the IC is shown in fig.2 for reference.

All data transfer operations are synchronized to a serial clock input CLKIN provided through a crystal oscillator. The IC generates the low frequency logic output at pins F1 and F2. The IC specification states that, for every 100 pulses at the output correspond to 1 kwhr. The logic output is shifted out of the chip through a ZigBee receiver and transmitted wirelessly as described in the next section.

A fault is generated when the phase and neutral (return) currents differ by more than 12.5%. This fault is sent to alarm information to the consumer online. But, there is no interruption of accurate reading and billing due to this. The calculation is continued using the larger of the two currents. This will eliminate false detection of a fault due to noise at light loads.

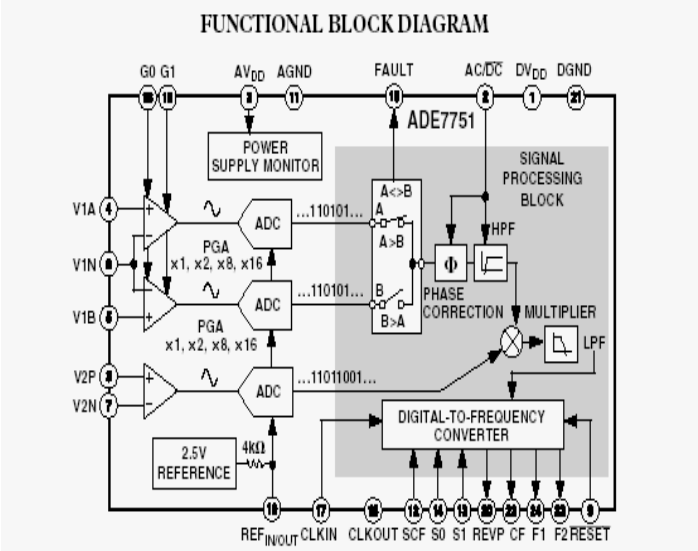

Figure 2. Functional internal Diagram of the IC ADE7751

The meter circuit needs a provision for recalibration. The voltage channel is simply calibrated by attenuating the line voltage. The line voltage attenuation is carried out by a simple resistor divider circuit shown in figure as calibration network. Similarly the current channels are calibrated by calibration network, consisting of parallel resistors and jumpers.

B. Wireless transmission through ZigBee network

The main characteristics of ZigBee network are simple implementation, low power consumption, low cost interface, simplicity in the configuration, redundancy of devices, high node density per physical layer (PHY), and medium access control layer (MAC). Besides, they allow the network to work with a great number of active devices. ZigBee is based on IEEE 802.15.4 standard in terms of the PHY and MAC layers [10]. IEEE 802.15.4 defines two kinds of devices: the Full Function Device (FFD) and the Reduced Function Device (RFD). The FFD has the function to coordinate the network and consequently has access to all other devices. The RFD is limited to a star topology configuration, not being able to work as a network coordinator, so it does not have all the protocol services. The FFD and RFD devices can operate in three different ways at the ZigBee standard: as the ZigBee coordinator (ZC), ZigBee Router (ZR), or ZigBee End Device (ZED) [10]. The network layer supports three topologies: star, cluster tree, and mesh, according to Fig. 3. A star topology consists of a coordinating node and of one or more FFD or RFD which communicates with the ZC. At the cluster tree, the

final devices can be associated to the network by the ZC and the ZR helping the increasing of number of nodes and the network scope. At the mesh topology, the FFD can distribute messages directly to other FFD. To enter the network, each device receives an address given by ZC or a ZR.

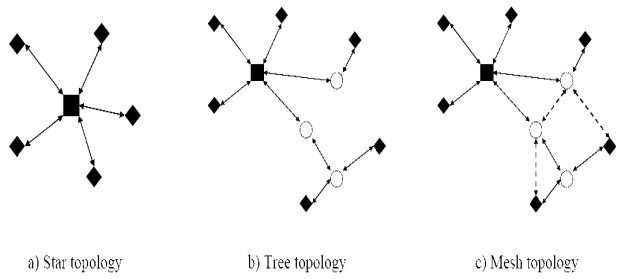

Figure 3. Different topologies of ZigBee network

The meter reading system adopts a distributed structure according to its characters. The system consists of data collector, wireless communication networks and the server system. Digital meter data is transmitted through two separate boards i.e. ZigBee transmission module to the data collector module. The ZigBee chip 2430 is suitable for the purpose. The CC2430 is a true System-on-Chip solution specifically tailored for IEEE 802.15.4 and ZigBee® applications. It combines the excellent performance of the leading CC2420 RF transceiver with an industry-standard enhanced 8051 MCU, 32/64/128 KB flash memory, 8 KB RAM and many other powerful features. [11] It has low noise, low power consumption.

The data collection rate (may be every an hour) can be adjusted according to the system requirement. The data collector is also a ZigBee gateway which is also a protocol conversion used to transform data package. The data package is transformed from ZigBee protocol to TCP/IP protocol before transmitting. So, the data collector sends the meter data to the receiver server through internet TCP/IP protocol. The socket client /server programming plays major role in case of long distance transmission. In the Fig. 4 a ZigBee wireless sensor network scheme is shown where a multiple data from energymeters installed at different locations are transferred to the data base server. In case of short distance (within the range of ZigBee network i.e. 100 meter [12]) the data collector is interfaced with a PC through RS-232 or USB (shown in the diagram Fig.1).

III. DATA MANAGEMENT SOFTWARE

The software developed here is to make an interactive, reliable and transparent relationship between the consumer and the electric supply agency. The system software is made using Visual Basic. It is an object-oriented programming development system for creating applications that run under any of the Microsoft Windows environments [13]. The program developed reads the data through the ZigBee receiver and gives the corresponding energy reading continuously similar to a connected conventional electromechanical meter. The software also gives user the opportunity of automatic billing i.e. the software makes the bill based on the current energy reading and the standard rates of energy given by the Energy Board. At any time the consumers can verify the meter reading, current billing information, next due date, the other

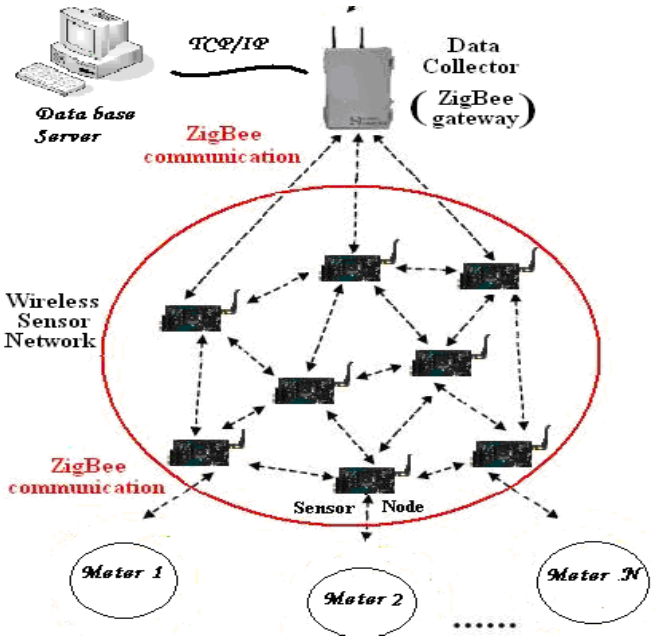

Figure 4. Long distance EM reading through ZigBee network

facilities as provided by the electric supply agency etc. from their internet connected computer by simply typing its unique consumer ID and password as shown in the window Fig. 5. The electric supply agency can also see the status of its any consumer without physically sending its employees at consumers' place. This is the main benefit of this software.

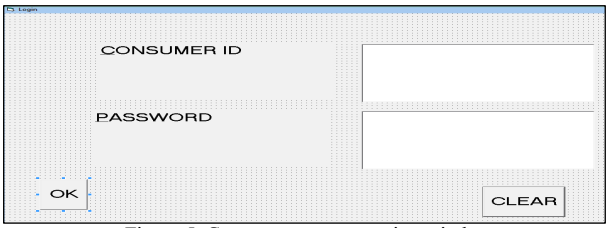

Figure 5. Consumer access starting window.

The electric supply agency also can access the individual consumers' information by its own password and user name. A sample of the information window is shown in Fig. 6. There is also a Billing Information window in general corresponds to the unit rates of energy under different levels of monthly consumption. As the unit rate varies normally with type of consumer, this is developed for five category of consumers viz. domestic, commercial, institute, public utility service and private hospitals/ educational institute. Though the access to this window is available for both consumer and administrator, only the administrator has the option to change the rates of the unit consumption. Again, the administrator can add new

consumer to the database based on their valid consumer number through the user-friendly data entry window.

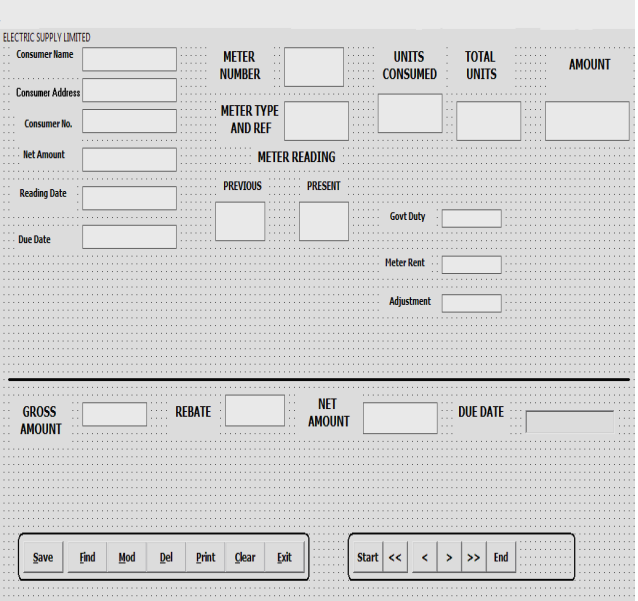

Figure 6. Consumer information window.

IV. EXPERIMENTAL RESULTS

Since the deployment of the wireless system with the help of ZigBee specification is still in its development stage, the wired version of the system described is developed and tested in the laboratory. A PCB is designed and fabricated based on the hardware circuit described in section IIA. The received energymeter data through this system is compared with the data of a connected calibrated wattmeter and a stopwatch under a load condition. The software is working satisfactorily. The results correspond to a sample test are presented in the Table I.

TABLE I. EXPERIMENTAL RESULTS

Observation Condition	***Theoretical Calculated Value Unit (KWhHr)***	***Display Result (KWHr)***
1. Supplied voltage= 220V Current = 1A	0.54	0.54
2. Supplied voltage= 200V Current =1.5A	0.78	0.80
3. Supplied voltage= 220V Current = 2A	1.40	1.43
4. Supplied voltage= 220V Current = 2.6A	2.20	2.26

V. CONCLUSION

The objective of developing a wireless energymeter-reading system is not only to have high accuracy over a wide current dynamic range, better reliability and robustness but also to face the weakening competence in meter reading in localities such as increasingly over crowded big cities, overpopulated rural, sub urban regions and remote or snowy districts. In order to accommodate the advanced requirements not available in electromechanical meters, manufacturers have begun adopting all-electronic solutions. With the system described, customer service is improved through remote and automated meter reading, more credible utility bills and efficient data management. New features such as multi-tariff billing, reactive energy management and power quality monitoring are also possible in this system to improve generation, distribution, customer service and billing. This will not only help the service providers of power to offload the manpower, the trouble to collect energymeter readings and organising bill preparation, but also provide consumers an online tracking system to regulate the energy bill ultimately.

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